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(54) Title: METHOD OF IMPLEMENTING BEAM TRACING IN A MILLIMETER WAVE COMMUNICATION-BASED COMMUNICATION SYSTEM

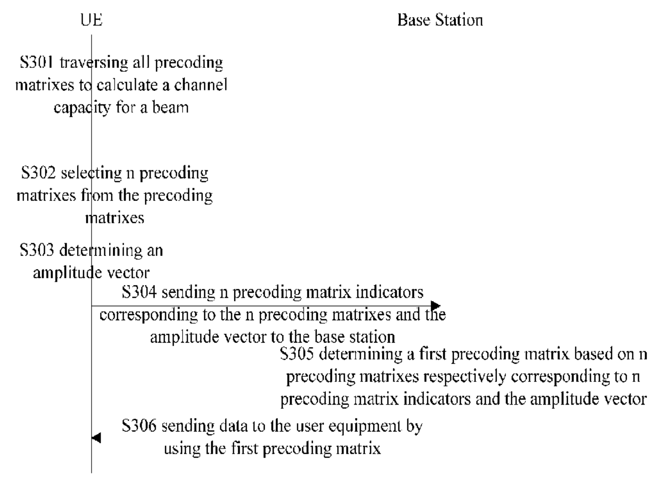

Fig. 3

(57) Abstract: The present invention provides a method and an apparatus of implementing beam tracing in a millimeter wave communication-based communication system. According an embodiment of the present invention, the method comprises: traversing ail precoding matrixes to calculate a channel capacity for a beam; selecting n precoding matrixes from the precoding matrixes, wherein the channel capacity calculated by using the n precoding matrixes is the top n maximum channel capacity in ail the calculated channel capacity; determining an amplitude vector, the amplitude vector consists of n channel performance indicators corresponding to the top n maximum channel capacity respectively; and sending n precoding matrix indicators corresponding to the n precoding matrixes and the amplitude vector to the base station. Through the present invention, multiple mobile user equipments can be supported with a high data rate in 5 G MMC networks.

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Method of Implementing Beam Tracing in a Millimeter Wave Communication-based Communication System

Field of the invention

The present invention generally relates to mobile communication technology, and particularly to a method and an apparatus of implementing beam tracing in a millimeter wave communication-based communication system.

Background of the invention

Millimeter Wave Communication (MMC) has been regarded as one of the key technologies in the 5G wireless network, which is expected to support Gigabit level data transmission. However, there is a big challenge in the propagation channel quality of millimeter wave due to the severe propagation loss. Fortunately, a compact antennal array can be well utilized in the MMC as the wave length is shorter than that in 4G networks.

Beam based transmission solution can significantly improve the channel quality and realize the high data rate transmission. But this transmission has some limitations:

1. This is more suitable for quasi-static transmission scenario. For a high mobility user, the performance will be degraded due to that the user may move out the coverage of the transmission beam.

2. The size of the code book is limited, and thus it is hard to realize the steering beam transmission by a single channel quality indicator (CQI) feedback.

Thus, it is necessary to design one fast beam-tracing solution to guarantee the beam-based high date transmission in 5G MMC networks.

Summary of the invention

In view of the above technical problem, one beam tracing solution, which is based on multiple CQI feedbacks, is proposed and it can be used to realize the steering beam transmission in MMC networks. Herein, it is referred as BT-MCQI (beam based transmission-multiple CQI). Through the present invention, multiple mobile user equipments can be supported with a high data rate in 5G MMC networks.

According to a first aspect of the present invention, it is provided a method, in a user equipment in a millimeter wave communication-based communication system, of assisting a base station to implement beam tracing, the method comprising: traversing all precoding matrixes to calculate a channel capacity for a beam; selecting n precoding matrixes from the precoding matrixes, wherein the channel capacity calculated by using the n precoding matrixes is the top n maximum channel capacity in all the calculated channel capacity; determining an amplitude vector, the amplitude vector consisting of n channel performance indicators corresponding to the top n maximum channel capacity respectively; and sending n precoding matrix indicators corresponding to the n precoding matrixes and the amplitude vector to the base station.

Advantageously, the amplitude vector is determined by the following equation:

$$\mathbf{a} = [1, \quad \alpha_1, ..., \alpha_{n-1}];$$

wherein α_{n-1} is a quotient between a channel performance indicator corresponding to the nth maximum channel capacity and a channel performance indicator corresponding to the maximum channel capacity.

Advantageously, the channel performance indicator includes: signal to noise ratio, signal to interference plus noise ratio or signal to noise and distortion ratio.

Advantageously, n equals to 2 or 3.

Advantageously, the column number of the precoding matrix corresponds to the number of rank in the communication system.

According to a second aspect of the present invention, it is provided a method, in a base station in a millimeter wave communication-based communication system, of implementing beam tracing, the method comprising: a. receiving n precoding matrix indicators and an amplitude vector from a user equipment, wherein the amplitude vector consists of n channel performance indicators, which correspond to n channel capacity respectively, the n channel capacity is the top n maximum channel capacity in all the calculated channel capacity obtained by the user equipment after traversing all precoding matrixes in order to calculate a channel capacity for a beam; b. determining a first precoding matrix based on n precoding matrixes respectively corresponding to the n precoding matrix indicators and the amplitude vector; and c. sending data to the user equipment by using the first precoding matrix.

Advantageously, the amplitude vector is

$$\mathbf{a} = [1, \quad \alpha_1, \ldots, \alpha_{n-1}];$$

wherein α_{n-1} is a quotient between a channel performance indicator corresponding to the n^{th} maximum channel capacity calculated by the user equipment and a channel performance indicator corresponding to the maximum channel capacity calculated by the user equipment, after the user equipment traverses all precoding matrixes in order to calculate a channel capacity for a beam.

Advantageously, the step b further includes:

b1. determining matrix $\bar{\mathbf{H}}$ by the following equation:

$$\bar{\mathbf{H}} = \left[\left[\mathbf{W}_{(1)}, \ldots, \mathbf{W}_{(n)} \right] \begin{pmatrix} 1 \cdot \mathrm{I} & 0 & \ldots & 0 \\ 0 & \alpha_1 \cdot \mathrm{I} & \ldots & 0 \\ \ldots & \ldots & \ldots & \ldots \\ 0 & 0 & 0 & \alpha_{n-1} \cdot \mathrm{I} \end{pmatrix} \right]^H;$$

wherein $\mathbf{W}_{(n)}$ is the nth precoding matrix, and I is a unit matrix with rank m;

b2. decomposing the matrix $\bar{\mathbf{H}}$ by singular value decomposition:

$$\bar{\mathbf{H}} = \mathbf{U}\boldsymbol{\Lambda}\mathbf{V}^{H}$$; and

b3. extracting the first m vertical vectors from the matrix $\mathbf{V}$ as the first precoding matrix;

wherein m corresponds to the number of the rank in the communication system.

According to a third aspect of the present invention, it is provided an apparatus, in a user equipment in a millimeter wave communication -based communication system, of assisting a base station to implement beam tracing, the apparatus comprising: calculating unit, for traversing all precoding matrixes to calculate a channel capacity for a beam; selecting unit, for selecting n precoding matrixes from the precoding matrixes, wherein the channel capacity calculated by using the n precoding matrixes is the top n maximum channel capacity in all the calculated channel capacity; determining unit, for determining an amplitude vector, the amplitude vector consisting of n channel performance indicators corresponding to the top n maximum channel capacity respectively; and sending unit, for sending n precoding matrix indicators corresponding to the n precoding matrixes and the amplitude vector to the base station.

According to a fourth aspect of the present invention, it is provided an apparatus, in a base station in a millimeter wave communication-based communication system, of implementing beam tracing, the apparatus comprising: receiving unit, for receiving n precoding matrix indicators and an amplitude vector from a user equipment, wherein the amplitude vector consists of n channel performance indicators, which correspond to n channel capacity respectively, the n channel capacity is the top n maximum channel capacity in all the calculated channel capacity obtained by the user equipment after traversing all precoding matrixes in order to calculate a channel capacity for a beam; determining unit, for determining a first precoding matrix based on n precoding matrixes respectively corresponding to n precoding matrix indicators and the amplitude vector; and sending unit, for sending data to the user equipment by using the first precoding matrix.

Brief description of drawings

Other features, objects and advantages of the invention will become more apparent upon review of the following detailed description of non-limiting embodiments taken with reference to the drawings in which:

Figure 1 shows a beam gain illustration according to one embodiment of the present invention;

Figure 2 shows an optimized steering beam according to one embodiment of the present invention;

Figure 3 shows a flowchart of a method of implementing beam tracing according to one embodiment of the present invention;

Figure 4 shows an apparatus diagram at a user equipment side for implementing beam tracing according to one embodiment of the present invention; and

Figure 5 shows an apparatus diagram at a base station side for implementing beam tracing according to one embodiment of the present invention.

In the drawings, identical or like reference numerals denote identical or corresponding components or features throughout the different figures.

Detailed description of embodiments

The basic idea of the present invention is in that: in BT-MCQI, a user equipment feeds back multiple CQIs to a base station simultaneously in one time slot, which include multiple PMIs (Precoding Matrix Indicator) and an amplitude vector, for example. Those parameters are utilized to optimize the transmit beam, such that the transmit beam can align/trace the user equipment accurately. The proposed invention has the following features for example:

1. Optimized beam can better match the propagation channel to realize the steering beam transmission, and achieve higher performance gain.

2. Realizing a more smoothly beam tracing and offering stable user specific services, such as offering data transmission with a stable rate for the specified user equipment.

3. Relaxing the requirement of the feedback period, and reducing the system overhead.

In the following, the embodiments of BT-MCQI will be described in detail with reference to scenario Figs. 1 and 2 in combination with the method flowchart in Fig.3.

Figure 1 shows a beam gain illustration according to one embodiment of the present invention. As shown in Fig.1, to improve the channel quality, a transmit beam group is used to over all the cell area. For example, in Fig.1, k beams are designed to cover the whole cell area. Those k beams can change dynamically. In Fig.1, there is one user equipment (UE) associated with the m-th beam. The antenna gain of UE subject from the m-th beam is a_m, and the antenna gain of the n-th beam is a_n.

In a traditional system, a UE will feedback a PMI to the base station. Then, the base station will determine the MSC level to be used and etc. therefrom. However, if the UE moves from the m-th beam to the n-th beam, the achieved beam gain of the m-th beam is continuous decreasing. This will degrade the system performance. Even if the UE is not moving, it cannot get the greatest beam gain due to the limited code book size.

Thus, in order to overcome those potential problems and improve the system performance, multiple CQIs would be designed to be feed back to the base station to optimize the transmit beam.

Figure 3 shows a flowchart of a method of implementing beam tracing according to one embodiment of the present invention.

As shown in step S301 in Fig.3, a UE traverses all precoding matrixes to calculate a channel capacity for a beam. Herein, the UE will use all the precoding matrixes in the code book to calculate a channel capacity for beam i.

For exemplary illustration, in an embodiment of the present invention, the channel capacity C_i can be calculated by using equation 1:

$$c_i = \sum_{z=1}^{Z} \log_2 \left| \mathbf{I} + (\mathbf{H}_z \mathbf{W}_i)(\mathbf{H}_z \mathbf{W}_i)^H \right| \qquad (1)$$

wherein Z is the number of the subcarriers in this beam, matrix H_z is the channel matrix, matrix I is a unit matrix, and $\mathbf{W}_i$ is the precoding matrix.

In step S302, the UE selects n precoding matrixes from all the precoding matrixes, wherein the channel capacity calculated by using the n precoding matrixes is the top n maximum channel capacity in all the calculated channel capacity. Herein, n is an integer greater than 1.

In an advantageous embodiment of the present invention, n is 2 or 3.

Herein, the column number of the used precoding matrix corresponds to the number of rank in the communication system. For example, when rank is 1, that is, when one stream is transmitted, one column is selected as a precoding matrix. When rank is 2, that is, when two streams are transmitted, a group of two columns is selected as a precoding matrix.

In this step, based on the criterion of maximum channel capacity, multiple precoding matrixes are selected according to the descend order of the achievable channel capacity.

Herein, the illustration would be given for the exemplary situation, where a transmit beam is optimized based on two CQIs feedback (i.e. n equals 2). Thus, two precoding matrixes $\mathbf{W}_{(1)}$ and $\mathbf{W}_{(2)}$, which can achieve the greatest channel capacity $c_{(1)}$ and the second greatest channel capacity $c_{(2)}$ respectively, are selected. In fact, in this step, the UE determines the precoding matrixes $\mathbf{W}_{(1)}$ and $\mathbf{W}_{(2)}$, which are associated with the m-th beam and the n-th beam in Fig.1, respectively. The channel capacity $c_{(1)}$ and $c_{(2)}$ are the channel capacity of the m-th beam and the channel capacity of the n-th beam respectively.

In step S303, the UE determines an amplitude vector. This amplitude vector is used to provide the power indication for the base station, such that the base station can determine the direction divergence of the UE, whether the UE diverges to the m-th beam or diverges to the n-th beam, for example.

In this step, the UE will derive the corresponding n channel performance indicators from the top n maximum channel capacity obtained in the last step, and construct the amplitude vector with those n channel performance indicators.

Herein, the channel performance indicator includes: signal to noise ratio, signal to interference plus noise ratio or signal to noise and distortion ratio.

Advantageously, the amplitude vector is determined by equation 2:

$$\mathbf{a} = \left[1, \quad \alpha_1, ..., \alpha_{n-1}\right] \qquad (2)$$

wherein α_{n-1} is a quotient between a channel performance indicator corresponding to the nth maximum channel capacity and a channel performance indicator corresponding to the maximum channel capacity.

The following detail illustration would still be based on n equals 2:

$$\mathbf{a} = \left[1, \quad \alpha_1\right]$$

α_1 is the quotient between a channel performance indicator corresponding to the 2^{th} maximum channel capacity and a channel performance indicator corresponding to the maximum channel capacity.

When the channel performance indicator is the signal to noise ratio, α_1 can be determined by using equation 3, for example:

$$\mathbf{a} = [1, \quad \alpha_1] = \left[1, \quad \frac{2^{c_{(2)}-1}}{2^{c_{(1)}-1}}\right] \qquad (3)$$

$c_{(1)}$ and $c_{(2)}$ in the equation are the maximum channel capacity and the 2^{nd} maximum channel capacity determined above.

It is appreciated for those skilled in the art that the above embodiment is only exemplary. In a different criterion, the amplitude vector can be determined by other ways.

In step S304, the UE sends n PMIs corresponding to the n precoding matrixes and the amplitude vector to the base station. When n equals to 2, α_1 can be sent instead of sending the amplitude vector.

In step S305, the base station determines a first precoding matrix based on n precoding matrixes respectively corresponding to n PMIs and the amplitude vector. That is, in this step, the base station will determine a new precoding matrix.

This can be determined by using a general function shown in equation 4 for example:

$$\mathbf{W} = func\left(\mathbf{W}_{(1)} \ldots \mathbf{W}_{(n)}, \alpha_1 \ldots \alpha_{n\text{-}1}\right) \qquad (4)$$

$\mathbf{W}_{(1)}$ to $\mathbf{W}_{(n)}$ correspond to a 1^{st} procoding matrix to a n^{th} precoding matrix, respectively.

Similarly, when n equals to 2, the following general function can be used:

$$\mathbf{W} = func\left(\mathbf{W}_{(1)}, \mathbf{W}_{(2)}, \alpha_1\right)$$

The following will give an example for the above general function. It should be appreciated for those skilled in the art that the following embodiment is only exemplary, but not limited.

Firstly, the matrix $\bar{\mathbf{H}}$ is determined by using equation 5:

$$\bar{\mathbf{H}} = \left[\left[\mathbf{W}_{(1)}, \ldots, \mathbf{W}_{(n)} \right] \begin{pmatrix} 1 \cdot \mathrm{I} & 0 & \ldots & 0 \\ 0 & \alpha_1 \cdot \mathrm{I} & \ldots & 0 \\ \ldots & \ldots & \ldots & \ldots \\ 0 & 0 & 0 & \alpha_{n-1} \cdot \mathrm{I} \end{pmatrix} \right]^H \quad (5)$$

wherein, as described above, $\mathbf{W}_{(n)}$ is a n$^{\text{th}}$ precoding matrix, and the n precoding matrixes in equation 5 form a new matrix, I is a unit matrix with rank m.

For example, when rank is 1, $\alpha_{n-1} \cdot \mathrm{I}$ will be a value. When rank is 2, $\alpha_{n-1} \cdot \mathrm{I}$ will be a matrix with 2×2.

Then, the matrix $\bar{\mathbf{H}}$ is decomposed by singular value decomposition:

$$\bar{\mathbf{H}} = \mathbf{U}\mathbf{\Lambda}\mathbf{V}^H \quad (6)$$

Then, the first m vertical vectors are extracted from the matrix $\mathbf{V}$ as the first precoding matrix, wherein m corresponds to the number of rank in the communication system. For example, when rank is 1, that is, when one stream is transmitted, the first vertical vector is selected as the first precoding matrix. When rank is 2, that is, when two streams are transmitted, the first two vertical vectors are selected as the first precoding matrix.

The following illustration is based on n equals 2 and rank is 1, for example. In this situation, equation 5 is transformed as:

$$\bar{\mathbf{H}} = \left[\left[\mathbf{W}_{(1)}, \mathbf{W}_{(2)} \right] \begin{pmatrix} 1 & 0 \\ 0 & \alpha_1 \end{pmatrix} \right]^H$$

Then, primary vectors can be extracted by channel singular value decomposition still according to equation 6. Similarly, a first vector group is extracted from the matrix $\mathbf{V}$. Since the number of the column depends on the number of rank in the communication system, the first column vector would be thereby extracted.

This step achieves the optimization for the transmit beam, as shown in Fig.2. By using this new precoding matrix, a new beam would be generated, as shown in the oblique line area.

When n=2, this means that a new beam is derived according to the m-th beam and the n-th beam.

In step S306, the base station sends data to the UE by using the first precoding matrix. As shown in Figs.1 and 2, it is clearly shown that the optimized beam can be steered to the UE better, and the channel quality and system performance is enhanced.

Figure 4 shows an apparatus diagram at a user equipment side for implementing beam tracing according to one embodiment of the present invention.

As shown in Fig. 4, the apparatus 40 includes a calculating unit 401, a selecting unit 402, a determining unit 403 and a sending unit 404.

The calculating unit 401 is configured for traversing all precoding matrixes to calculate a channel capacity for a beam.

The selecting unit 402 is configured for selecting n precoding matrixes from the precoding matrixes, wherein the channel capacity calculated by using the n precoding matrixes is the top n maximum channel capacity in all the calculated channel capacity.

The determining unit 403 is configured for determining an amplitude vector, the amplitude vector consisting of n channel performance indicators corresponding to the top n maximum channel capacity respectively.

The sending unit 404 is configured for sending n precoding matrix indicators corresponding to the n precoding matrixes and the amplitude vector to the base station.

Figure 5 shows an apparatus diagram at a base station side for implementing beam tracing according to one embodiment of the present invention.

As shown in Fig. 5, the apparatus 50 includes a receiving unit 501, a determining unit 502 and a sending unit 503.

The receiving unit 501 is configured for receiving n precoding matrix indicators and an amplitude vector from a user equipment, wherein the amplitude vector consists of n channel performance indicators, which correspond to n channel capacity respectively, the n channel capacity is the top n maximum channel capacity in all the calculated channel capacity obtained by the user equipment after traversing all precoding matrixes in order to calculate a channel capacity for a beam.

The determining unit 502 is configured for determining a first precoding matrix based on n precoding matrixes respectively corresponding to n precoding matrix indicators and the amplitude vector.

The sending unit 503 is configured for sending data to the user equipment by using the first precoding matrix.

From the above analysis, the smoothly beam tracing is realized instead of the previous discrete beam tracing based on codebook in the prior art. Thereby, a more accurate steering beam can be implemented for data transmission.

1. Due to the optimized beam aligns its bore sight direction to user as more possible, this ensures the user locates in the center area of the beam coverage and needs more time (T_0) to move out the beam coverage. Given the speed, the larger value of T_0, the longer period of CQI feedback can be accepted. This means the system overhead can be significantly reduced.

2. The smoothly beam tracing indicates that the stable beam gain can be achieved and a more stable transmission rate is ensured, and the user experience is enhanced.

This solution according to the present invention can also be applied for the channel measurement based on pre-coded CSR-RS. The PMIs and the amplitude vector are feedback to the base station for beam optimization.

It shall be appreciated that the foregoing embodiments are merely illustrative but will not limit the invention. Any technical solutions without departing from the spirit of the invention shall fall into the scope of invention, including that different technical features, methods appearing in different embodiments are used to combine to advantage.

Further, any reference numerals in the claims cannot be recognized as limiting the related claims; the term “comprise” will not preclude another apparatus or step which does not appear in other claims or the description.

CLAIMS

1. A method, in a user equipment in a millimeter wave communication-based communication system, of assisting a base station to implement beam tracing, the method comprising:

traversing all precoding matrixes to calculate a channel capacity for a beam;

selecting n precoding matrixes from the precoding matrixes, wherein the channel capacity calculated by using the n precoding matrixes is the top n maximum channel capacity in all the calculated channel capacity;

determining an amplitude vector, the amplitude vector consisting of n channel performance indicators corresponding to the top n maximum channel capacity respectively; and

sending n precoding matrix indicators corresponding to the n precoding matrixes and the amplitude vector to the base station.

2. The method according claim 1, wherein the amplitude vector is determined by the following equation:

$$\mathbf{a} = [1, \quad \alpha_1, ..., \alpha_{n-1}];$$

wherein α_{n-1} is a quotient between a channel performance indicator corresponding to the n^{th} maximum channel capacity and a channel performance indicator corresponding to the maximum channel capacity.

3. The method according to claim 1 or 2, wherein the channel performance indicator includes: signal to noise ratio, signal to interference plus noise ratio or signal to noise and distortion ratio.

4. The method according to claim 1, wherein n equals to 2 or 3.

5. The method according to claim 1, wherein the column number of the precoding matrix corresponds to the number of rank in the communication system.

6. A method, in a base station in a millimeter wave communication-based communication system, of implementing beam tracing, the method comprising:

a. receiving n precoding matrix indicators and an amplitude vector from a user equipment, wherein the amplitude vector consists of n channel performance indicators, which correspond to n channel capacity respectively, the n channel capacity is the top n maximum channel capacity in all the calculated channel capacity obtained by the user equipment after traversing all precoding matrixes in order to calculate a channel capacity for a beam;

b. determining a first precoding matrix based on n precoding matrixes respectively corresponding to the n precoding matrix indicators and the amplitude vector; and

c. sending data to the user equipment by using the first precoding matrix.

7. The method according to claim 6, wherein the amplitude vector is

$$\mathbf{a}=[1, \quad \alpha_1,.....,\alpha_{n-1}];$$

wherein α_{n-1} is a quotient between a channel performance indicator corresponding to the nth maximum channel capacity calculated by the user equipment and a channel performance indicator corresponding to the maximum channel capacity calculated by the user equipment, after the user equipment traverses all precoding matrixes in order to calculate a channel capacity for a beam.

8. The method according to claim 7, wherein the step b further includes:

b1. determining matrix $\bar{\mathbf{H}}$ by the following equation:

$$\bar{\mathbf{H}}=\left[\left[\mathbf{W}_{(1)},...,\mathbf{W}_{(n)}\right]\begin{pmatrix}1\cdot\mathrm{I} & 0 & ... & 0\\ 0 & \alpha_1\cdot\mathrm{I} & ... & 0\\ ... & ... & ... & ...\\ 0 & 0 & 0 & \alpha_{n-1}\cdot\mathrm{I}\end{pmatrix}\right]^H;$$

wherein $\mathbf{W}_{(n)}$ is the nth precoding matrix, and I is a unit matrix with rank m;

b2. decomposing the matrix $\bar{\mathbf{H}}$ by singular value decomposition:

$$\bar{\mathbf{H}}=\mathbf{U}\mathbf{\Lambda}\mathbf{V}^H; \text{ and}$$

b3. extracting the first m vertical vectors from the matrix $\mathbf{V}$ as the first precoding matrix;

wherein m corresponds to the number of the rank in the communication system.

9. The method according to claim 7, wherein the channel performance indicator includes: signal to noise ratio, signal to interference plus noise ratio or signal to noise and distortion ratio.

10. The method according to claim 6, wherein n equals to 2 or 3.

11. An apparatus, in a user equipment in a millimeter wave communication-based communication system, of assisting a base station to implement beam tracing, the apparatus comprising:

calculating unit, for traversing all precoding matrixes to calculate a channel capacity for a beam;

selecting unit, for selecting n precoding matrixes from the precoding matrixes, wherein the channel capacity calculated by using the n precoding matrixes is the top n maximum channel capacity in all the calculated channel capacity;

determining unit, for determining an amplitude vector, the amplitude vector consisting of n channel performance indicators corresponding to the top n maximum channel capacity respectively; and

sending unit, for sending n precoding matrix indicators corresponding to the n precoding matrixes and the amplitude vector to the base station.

12. An apparatus, in a base station in a millimeter wave communication-based communication system, of implementing beam tracing, the apparatus comprising:

receiving unit, for receiving n precoding matrix indicators and an amplitude vector from a user equipment, wherein the amplitude vector consists of n channel performance indicators, which correspond to n channel capacity respectively, the n channel capacity is the top n maximum channel capacity in all the calculated channel capacity obtained by the user equipment after traversing all precoding matrixes in order to calculate a channel capacity for a beam;

determining unit, for determining a first precoding matrix based on n precoding matrixes respectively corresponding to n precoding matrix indicators and the amplitude vector; and

sending unit, for sending data to the user equipment by using the first precoding matrix.

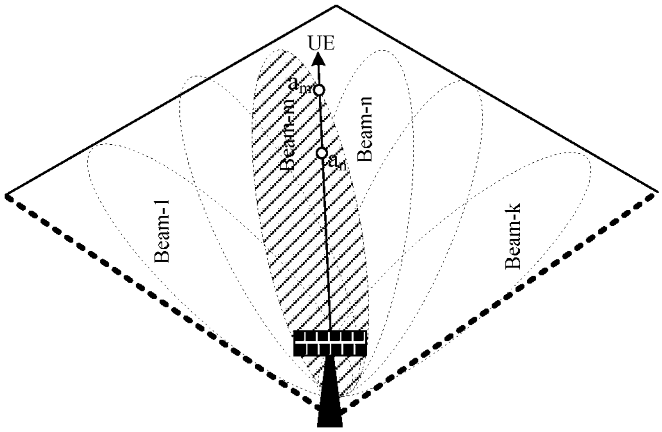

Fig.1

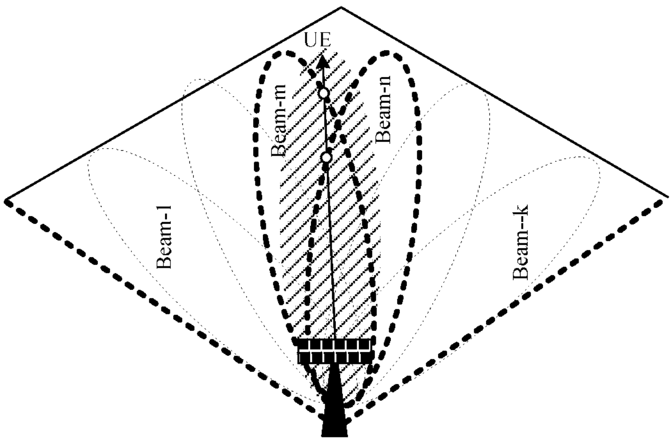

Fig. 2

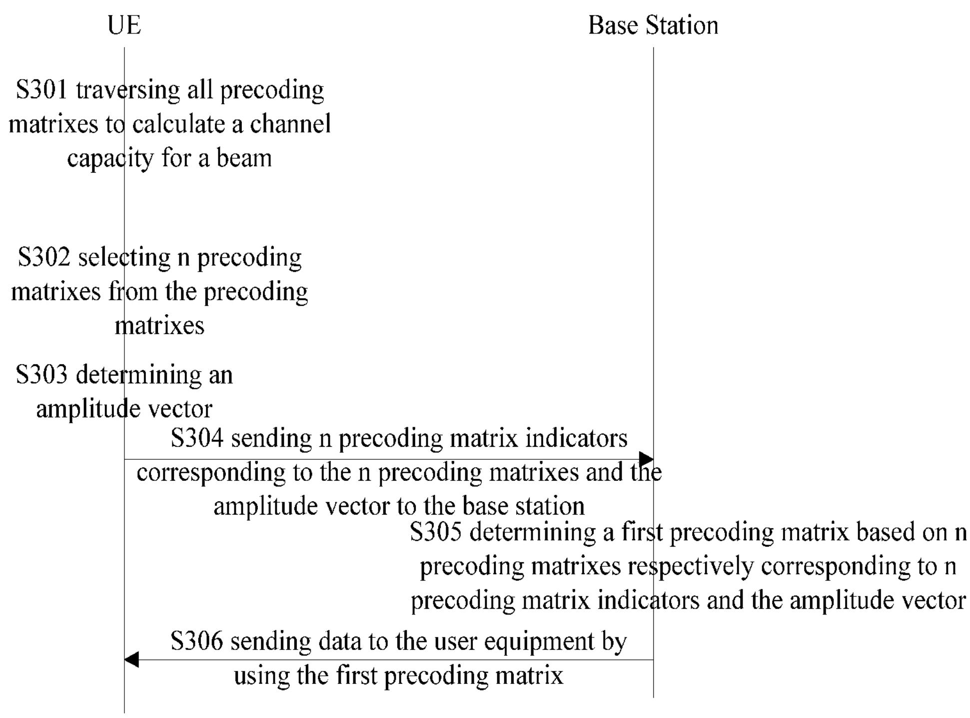
UE
Base Station
S301 traversing all precoding matrixes to calculate a channel capacity for a beam
S302 selecting n precoding matrixes from the precoding matrixes
S303 determining an amplitude vector
S304 sending n precoding matrix indicators corresponding to the n precoding matrixes and the amplitude vector to the base station
S305 determining a first precoding matrix based on n precoding matrixes respectively corresponding to n precoding matrix indicators and the amplitude vector
S306 sending data to the user equipment by using the first precoding matrix

Fig. 3

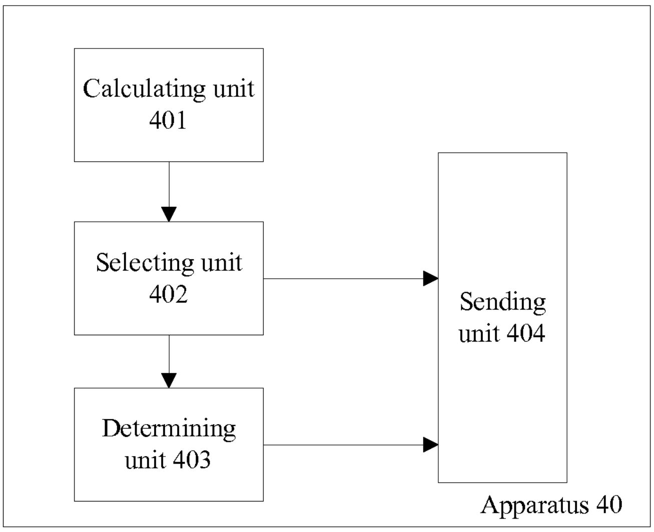
Calculating unit 401
Selecting unit 402
Determining unit 403
Sending unit 404
Apparatus 40

Fig.4

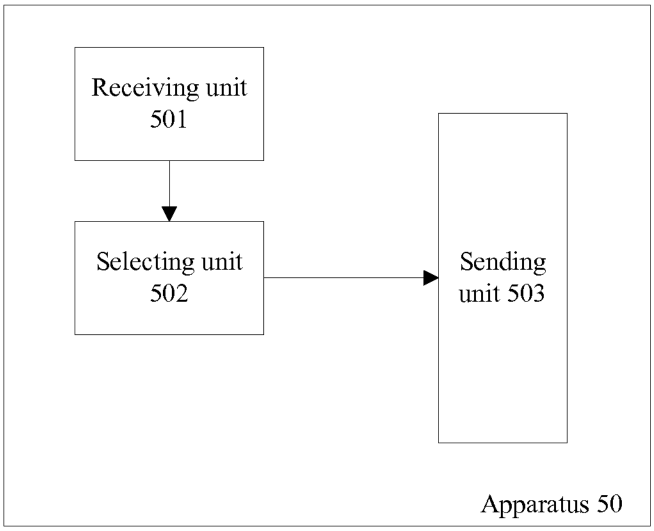
Receiving unit 501
Selecting unit 502
Sending unit 503
Apparatus 50

Fig.5

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2016/000955

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04B7/04 H04B7/06
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US 2014/233513 A1 (XU WENYING [CN] ET AL) 21 August 2014 (2014-08-21) abstract; figure 1 paragraph [0010] paragraph [0035] - paragraph [0048] -----	1,3-6, 10-12 2,7-9
A	US 2015/103934 A1 (NAM JUNYOUNG [KR] ET AL) 16 April 2015 (2015-04-16) abstract; figures 1-2 -----	1-10

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 September 2016	29/09/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Bauer, Frédéric

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2016/000955

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2014233513 A1	21-08-2014	CN 103095420 A	08-05-2013
		US 2014233513 A1	21-08-2014
		WO 2013064044 A1	10-05-2013
US 2015103934 A1	16-04-2015	NONE	